Ch. 39

Plant Responses to Internal and External Signals
Essential Question:

How do plants respond to internal and external stimuli?
plants use signal transduction pathways to respond to stimuli

**etiolation** - plant morphological adaptations to growth in darkness
   - ex. potato produces long spindly stems if in the dark for a long time, penetrate the soil

**de-etiolation** - (greening) - changes a plant shoot undergoes in the presence of sunlight
   - elongation of stem slows
   - leaves expand
   - roots start to elongate
   - shoot produces chlorophyll
general model of signal transduction

receptor - proteins that receive a stimulus
  ex. phytochrome - a photoreceptor
    -functions in the cytoplasm as a light detector
Transduction - second messengers - small, internally produced chemicals that transfer and amplify the signal from the receptor to other proteins that cause a response.

Role of phytochrome in greening process.
Response - a regulation of a cell activity

two mechanisms a signaling pathway activates an enzyme
  1. stimulating transcription of mRNA for the enzyme (transcription regulation)
     -transcription factors bind to regions of DNA and control transcription
     -positive and negative transcription factors (increase and decrease transcription respectively)
  2. activating existing enzymes (post-translational modification)
     -modifying the proteins by phosphorylation
     -protein kinase cascade
     -can turn genes on or off
     -protein phosphatases - dephosphorylate proteins to "switch-off" genes
role of phytochrome in greening process
Proteins that are transcribed or activated during de-etiolation process:

1. enzymes needed for photosynthesis
2. enzymes for making chemical precursors for chlorophyll production
3. affect hormone levels

**Hormones** are chemical signals that affect different parts of an organism
- chemicals produced by one part of the organism and then transported to another part and triggers a response
- only needed on small amounts to have an effect
- control plant growth by affecting the division, elongation, and differentiation of cells
plant people call hormones **plant growth regulators**
- because they can regulate locally
Tropism- a growth response that results in curvatures of whole plant organs toward or away from a stimulus

Phototropism - light is stimulus
positive phototropism - moves towards light
negative phototropism - moves away from light
Survey of Plant Hormones
Auxin- chemical substance that promotes elongation of coleoptiles
- natural auxin is indolacetic acid or IAA
- transported through parenchyma tissue, one cell to next
- moves only from shoot tip to base (called polar transport - independent of gravity)

How does it promote elongation?
- synthesized in apical meristem of shoot
- moves down to region of cell elongation
- stimulates plasma membrane's proton pumps (causes voltage) and lowers pH of cell wall
- low pH activates enzymes - expansins - break cross-links between cellulose microfibrils so cells can elongate
- water enters cell - increases turgor
cell elongation
Polar Auxin transport - a chemiosmotic model
Auxins are used in vegetative propagation
-if a leaf or stem is cut and auxin is added to the cut end, adventitious roots form near cut surface

-also helps in branching of roots (lateral roots)

Auxins as herbicides
-synthetic auxins used
-won't kill maize, turfgrass - inactivate synthetic auxin
-kills eudicots (weeds) - hormonal overdose

Auxins in fruit formation
-induces cell division in vascular cambium and differentiates secondary xylem
-synthetic auxins promote fruit development without pollination
Cytokinins - chemical substances that stimulate cytokinesis
  
  Zeatin - most common type of cytokinin in plants

-stimulate cell division and differentiation in conjunction with auxin
-if auxin and cytokinin in equal amounts get callus growing
-if cytokinin levels are higher than auxin, shoot buds develop
-if auxin levels higher than cytokinin, roots form

-helps control apical dominance
  
  direct inhibition hypothesis -
    auxin inhibits axillary buds
     cytokinins signal axillary buds to grow
  -if auxin removed (terminal bud removed) plant gets bushier
-anti-aging effects
  -inhibit protein breakdown
  -stimulate RNA and protein synthesis
  -slow leaf deterioration
  -used as a spray to keep flowers fresh
Apical Dominance:
with apical bud   without apical bud
Giberillins

effect:
1. stem elongation - dwarf plants can grow to normal height if treated with giberillins
   Ex. in lettuce when giberillins present lets floral buds grow tall
2. Fruit Growth
   -used in spraying of Thompson seedless grapes - grow larger
   -internodes elongate - more space for grapes to grow

3. Germination
   -embryo - large source of giberillins
   -when water absorbed in embryo, giberillins released - seed germinates
Brassinosteroids

- induce cell elongation and division in stems
- retard leaf abscission
- promote xylem differentiation

Abscisic Acid

- slows growth
- seed dormancy
  - inhibit germination
- drought tolerance
  - allows plants to withstand drought, causes stomata to close
    (loss of potassium ions)
Ethylene

produced in Response to mechanical stress
-triple response-if shoot is up against an obstacle if germinating
a. slowing stem elongation
b. thickens the stem
c. curves the stem so grows horizontally
- **senescence** = programmed death of certain cells or organs or the entire plant

**programmed cell death - apoptosis**

**leaf abscission** - causes cells to produce enzymes that digest cellulose in abscission layer (parenchyma cells)
- purpose - prevent dessication during periods where water is scarce
- elements are salvaged from leaves and stored in stems until spring

**fruit ripening** - triggers ripening, ripening triggers more ethylene production (positive feedback)
- can get fruit to ripen faster if put in paper bag so ethylene gas accumulates
Plant Response to light
-used for photosynthesis
-used for **photomorphogenesis** - changes in plant structure
-used for measurement of days/seasons

-plants detect presence, direction, intensity, and wavelength of light

**action spectrum**- wavelength spectrum that cause changes in plant
two major classes of photoreceptors

1. Blue-light photoreceptors
   induces:
   a. phototropism by phototropin receptors
   b. opening of stomata by zeaxanthin
   c. slowing of hypocotyl elongation when seedling breaks ground by cryptochromes
2. Phytochromes
   -important for germinating process, detect sunlight, and once plant is grown- helps determine quality of light
     -affected by red (660nm) and far red light (730nm)
     -red light - causes germination, far red light inhibits germination
     -if plant is shaded, not getting red light but gets far red light programs plant to grow taller to reach sunlight
     -helps plant keep track of seasons and days
Phytochrome regulation of lettuce seed germination

Conclusion - red light stimulates germination, far-red inhibits germination. Final light is determining factor. Effects are reversible.
Pfr is the active form or phytochrome - it switches on the physiological and developmental responses in the plant
in lettuce seeds - when exposed to red light Pr is converted to Pfr to stimulate germination

phytochromes also provide information about quality of light
during day $P_r = P_{fr}$ for a dynamic equilibrium

If a tree is shaded phytochrome ratio shifts to $P_r$ because forest blocks out more red light than far red light causing a tree to grow taller

direct sunlight increases $P_{fr}$ to stimulate branching and decrease vertical growth
Circadian Rhythms - a physiological cycle of about 24 hours present in all eukaryotic organisms and continues even in the absence of external cues (like night and day)

Ex. plant raising leaves during day
daily production of certain photosynthesis proteins

can get desynchronized if left in different conditions (ex. time zone changes in plane trips)
Photoperiodism - a physiological response to a photoperiod (relative lengths of night and day)

**short-day plants** - a plant that flowers (usually in late summer, fall or winter) only when the light period is shorter than a critical length
- ex. poinsettias, chrysanthemums, some soybeans

**Long-day plants** - a plant that flowers (usually in late spring or early summer) only when the light period is longer than a critical length
- ex. spinach, radish, lettuce, iris

**Day-neutral plants** - plants that are unaffected by photoperiod and flower when they reach maturity
- ex. tomatoes, rice, dandelions

really based on length of continual darkness, not light
Chrysanthemums are short day plants - normally bloom in fall to get them for Mother's Day - growers turn one long night into two short days by using a flash of light.
What is happening here?
vernalization - using treatment of cold to induce flowering

leaves detect the photoperiods and then signal (florigen - hypothetical molecule for flowering - still unidentified) buds to develop
Effect of gravity on plants

**gravitropism** - response to gravity
- positive - grow towards ground (roots)
- negative - grow away from ground (shoots)
  - auxin is involved

detect gravity by settling **statoliths** - specialized plastids containing dense starch grains to lower portions of cells
  - roots located in root cap
Mechanical Stimuli on plants

**thigmomorphogenesis**- changes in the form that result from mechanical stimuli
- activates a signal transduction pathway that increases Calcium ions in cytosol

**thigmotropism** - directional growth in response to touch
- ex. tendrils of plants,
  "sensitive plant" - due to loss of turgor pressure in joints of leaf
  - once one leaflet touched causes and action potential through the other leaves
- Venus Flytrap - have hairs that undergo action potentials
Rapid turgor movements by sensitive plant
Environmental Stresses

1. Drought-
   plant tries to conserve water by reducing transpiration
   a. leaf guard cells lose turgor - so close stomata
   b. increases release of abscisic acid in leaf - also helps close stomata
   c. inhibits growth of young leaves - decreases surface area to minimize transpiration loss.
   d. leaves can roll up to decrease surface area reduces photosynthesis due to leaf changes
   e. roots- inhibits growth of shallow roots - lack of turgor
   f. causes growth of deep roots
2. Flooding

plants suffocate due to lack of air spaces in soil
mangroves - have aerial roots and submerged roots

ethylene causes root cells to undergo apoptosis (cell death)
so creates air tubes in roots ("snorkels")
3. **Salt stress**
- Lowers water potential of soil solution - reduces water uptake
- Sodium is toxic to plants in high concentrations

- Halophyte plants are salt tolerant
  - Have salt glands that pump salt across leaf epidermis
4. Heat Stress
- dentures enzymes
- evaporative cooling by leaves
  - closing stomata will reduce evaporative cooling
- synthesis of heat shock proteins - help prevent denaturation

5. Cold Stress
- alter lipid concentration in membranes
  - increase unsaturated fatty acids - keep membranes fluid
- rapid chilling is more stressful than slow chilling
- some plants increase their solutes in cytoplasm so less chance of freezing
Defense against herbivores
- thorns
- chemicals (distasteful or toxic)
  ex. canavanine - replaces arginine in proteins - affects conformation of resulting protein - insect dies
- have insects associated with them
  ex. parasitoid wasps - attracted by leaf that has been damaged by caterpillar due to volatile compounds
  - lay eggs in caterpillars that feed on plants
  - larvae eat caterpillar during development
- volatile compounds also signal nearby plants so can activate defense genes
Defense response to herbivore involving parasitoid wasp
Defense against Pathogens

-epidermis and periderm - pathogens can still enter if damaged via by stomata

gene-to-gene recognition - involves recognition of pathogen derived molecules by protein products of specific plant disease resistance genes (R genes)

-similar to our antibodies

virulent pathogens - pathogens that the plant can't defend against

avirulent pathogens - pathogens that invade plant, but don't kill it
gene-to-gene resistance of plants to pathogens
Responses to Pathogen invasions
elicitors - induce a defense response
ex. oligosaccharins
-stimulate production of antimicrobial compounds called
phytoalexins and PR proteins
-others signal infection to nearby cells
-increase lignin in cell walls to slow pathogen down

hypersensitive response - high production of phytoalexins and PR proteins that seal off infection

systemic acquired resistance- hypersensitive response "sounds the alarm" to the rest of the plant - so stimulates production of phytoalexins and PR proteins in rest of plant
-nonspecific response to multiple pathogens
-salicylic acid- activates systemic acquired resistance
Defense response against avirulent pathogen